Uncertainty Quantification Applied to the Analysis and Design of Hypersonic Inflatable Atmospheric Decelerators for Spacecraft Re-Entry

Completed Technology Project (2013 - 2017)

Project Introduction

The objective of the proposed research will be to efficiently quantify the uncertainty in the high-fidelity numerical modeling of hypersonic flows over hypersonic inflatable atmospheric decelerator (HIAD) configurations and implement a quantification of margins and uncertainties (QMU) framework to the design and analysis of HIAD systems. With the recent development of HIAD technology, uncertainty quantification will be an extremely important engineering tool to obtain robust and reliable inflatable decelerator configurations. The uncertainty analysis will involve the modeling and propagation of both inherent uncertainties (e.g., the variation in the velocity, altitude, and the orientation of the spacecraft and the uncertainty in the HIAD surface geometry description due to shape change) and model-form (epistemic) uncertainties in the physical models (e.g., non-equilibrium thermo-chemistry modeling, surface catalysis, radiative heat transfer modeling, and turbulence modeling including the transition location) associated with hypersonic flow field simulations over HIAD geometries. Among various output quantities of interest, the uncertainty in the heat flux to the surface of the HIAD will be quantified. The proposed research aims to implement advanced uncertainty quantification methods based on stochastic expansions (Non-intrusive Polynomial Chaos) to achieve both efficiency and accuracy as an alternative to traditional Monte Carlo methods, since high-fidelity hypersonic flow simulations over HIAD geometries are computationally expensive. Besides uncertainty quantification, the research efforts will also focus on the development and implementation of a quantification of margins and uncertainties (QMU) framework to the multidisciplinary analysis and design of HIAD systems (e.g., aerothermodynamics, structures, and material response), which can be used to obtain robust and reliable configurations in future studies. The developed uncertainty quantification and QMU methodologies will be general so that they can be applied to the design of various aerospace systems and vehicles of interest to NASA. It is believed that this research will directly help space exploration succeed by giving the designers and engineers a more accurate toolset to be used in their design and analysis of current HIAD technology.

Anticipated Benefits

The developed uncertainty quantification and QMU methodologies will be general so that they can be applied to the design of various aerospace systems and vehicles of interest to NASA. It is believed that this research will directly help space exploration succeed by giving the designers and engineers a more accurate toolset to be used in their design and analysis of current HIAD technology.

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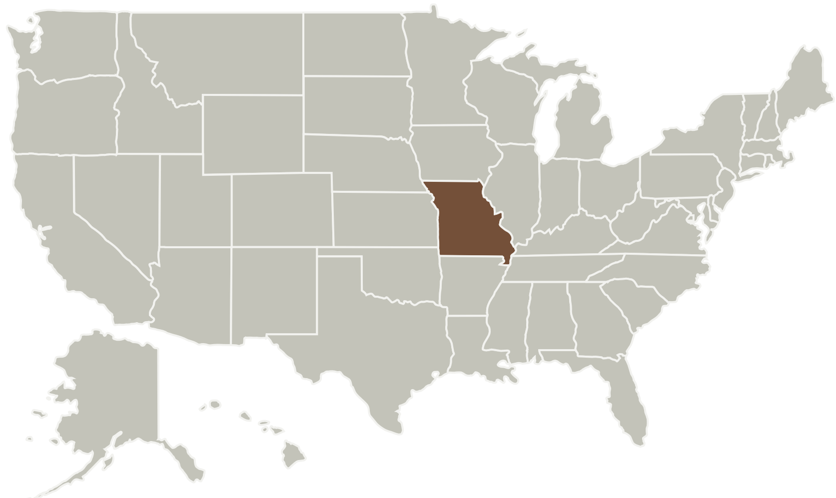
Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Missouri

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

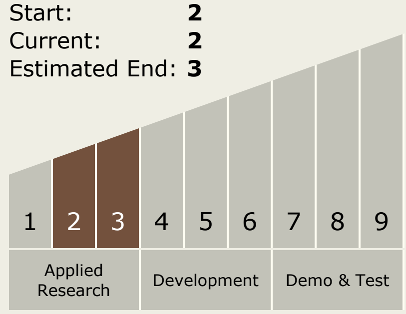
Serhat Hosder

Co-Investigator:

Andrew J Brune

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.5 Modeling and Simulation for EDL